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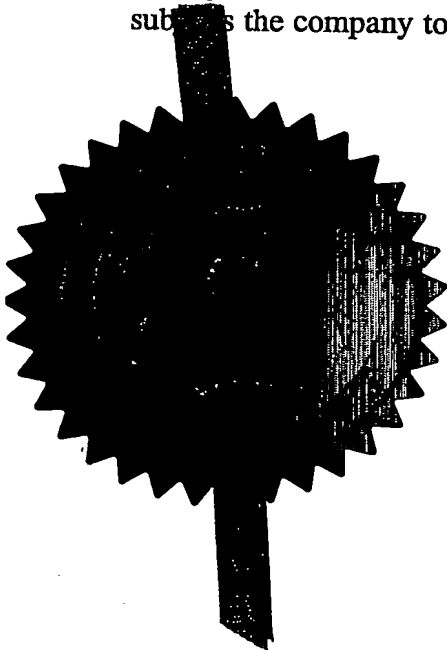
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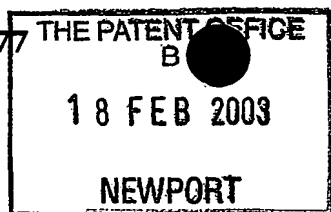


Signed

Stephen Hordley

Dated

6 October 2003



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Request for grant of a patent

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1. Your reference **AA 1599 GB**
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2. Patent application number
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3. Full name, address and postcode of the or of each applicant (underline all surnames)
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- Patents ADP number (if you know it)
- If the applicant is a corporate body, give the country/state of its incorporation **GB** **536268009**
-
4. Title of the invention **PROCESS FOR TREATING DIESEL EXHAUST GAS**
-
5. Name of your agent (if you have one) **ANDREW DOMINIC NUNN**
- "Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)
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a) any applicant named in part 3 is not an inventor, or
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PROCESS FOR TREATING DIESEL EXHAUST GAS

The present invention relates to a process for treating exhaust gases from a low-
5 temperature combustion diesel engine, especially when such exhaust gases include
unsaturated hydrocarbons.

Conventional diesel engines produce less gaseous hydrocarbon (HC) and carbon
monoxide (CO) than gasoline engines and it is possible to meet present legislated limits
10 for these components using a Pt-based diesel oxidation catalyst (DOC). Diesel NO_x
emissions are presently controlled by engine management, such as exhaust gas
recirculation (EGR). As a consequence, however, diesel particulate matter (PM)
emissions including volatile and soluble organic fractions (VOF and SOF) are increased.
The DOC is used to treat VOF and SOF in order to meet presently legislated limits for
15 PM.

Two ways of reducing diesel emissions, which can be used in addition to exhaust
gas aftertreatment, are engine management and engine design. More recently, new diesel
engines have been developed which use a range of engine management techniques to
20 lower the combustion temperature. One such technique is to provide means for
substantially pre-mixing the air-fuel charge.

An advantage of these techniques is that they can reduce NO_x and PM emissions,
without significantly increasing fuel consumption. An embodiment of the new generation
25 of diesel engines which employs these techniques is known as a Homogeneous Charge
Compression Ignition (HCCI) engine. Characteristics of an HCCI engine include
homogeneous fuel charge for external or internal mixture formation by variable valve
timing, increased swirl ratio, injection rate control (multiple injection) and adapted spray
configuration; high dilution rate for a moderate burn rate; low NO_x by charge dilution
30 and low combustion temperature; and low soot by prolonging the time for mixture
preparation and, consequently, homogenisation. All relative terms are compared to a
normal direct injection diesel engine.

Another new diesel engine is known as the Dilution Controlled Combustion
35 System (DCCS), for example Toyota's Smoke-less Rich Combustion concept.

Characteristics of DCCS include conventional direct injection; extremely high dilution rate to lower combustion temperature below soot formation threshold by increasing ignition lag, increase in swirl ratio, variable valve timing and injection rate control (multiple injection); low NO_x and soot by very high charge dilution rate and extremely low combustion temperature; and very high EGR rate. All relative terms are compared to a normal direct injection diesel engine.

We have investigated the emissions of a vehicle including an embodiment of the new generation of diesel engines, such as DCCS and HCCI diesel engines, and have found that, despite the improvements in reduced NO_x and PM, they can produce high levels of CO and HC relative to a conventional direct injection diesel engine. Such CO and HC emissions can be characterised by an exhaust gas composition of >2000ppm carbon monoxide (CO) and >500ppm C₁ unburnt hydrocarbon (HC) below 250°C during normal operating conditions.

Furthermore, we believe that unsaturated hydrocarbons may result from the incomplete combustion of the diesel, examples of which are ethylene, propylene, aromatics and polyaromatics. Release of certain unsaturated HCs is undesirable for environmental and health reasons.

We have now identified a family of catalysts that are particularly effective in converting relatively high levels of CO and HC at temperatures below 250°C. Indications are that such catalysts can also convert unsaturated HCs at such temperatures.

According to one aspect, the invention provides a process for treating an exhaust gas from a diesel engine, which exhaust gas comprises >2000ppm carbon monoxide (CO) and >500ppm C₁ unburnt hydrocarbon (HC) below 250°C during normal operating conditions measured at the exhaust manifold, which process comprising contacting the exhaust gas with a catalyst comprising at least one supported Platinum Group Metal (PGM) and at least one base metal promoter, wherein the at least one PGM is palladium (Pd) and wherein the atom amount of Pd present is in the majority over all other PGMs present (if any).

According to a further aspect, the invention provides a diesel engine producing an exhaust gas comprising >2000ppm carbon monoxide (CO) and >500ppm C₁ unburnt hydrocarbon (HC) below 250°C during normal operating conditions measured at the exhaust manifold, which engine comprising an exhaust system comprising a catalytic converter, which catalytic converter comprising at least one supported Platinum Group Metal (PGM) and at least one base metal promoter, wherein the at least one PGM is palladium (Pd) and wherein the atom amount of Pd present is in the majority over all other PGMs present (if any).

Such engines can be controlled, using engine management techniques operated by engine control means e.g. including a CPU and suitable pre-programming, to combust a substantially pre-mixed air-fuel charge.

Two embodiments of engines according to the invention fitted to commercially available vehicles are a homogeneous charge compression ignition (HCCI) diesel engine and a Dilution Controlled Combustion System (DCCS) diesel engine.

We have found that the promoted and supported Pd catalytic component of the catalytic converter according to the invention is at least of zero order kinetics for CO, i.e. the rate of reaction stays the same regardless of the CO concentration. We have also found that for certain of the Pd catalytic components we have identified the rate of reaction is first order for CO, i.e. the more CO, the faster the rate of reaction. By contrast, a widely used PGM in DOCs, platinum (Pt), can be negative order in CO, i.e. the more CO, the lower the reaction rate.

The realisation of the kinetics of promoted and supported Pd catalytic components to the CO reaction has led us to consider uses for the exotherm produced. One such use is to increase the rate of a downstream process step, as described in greater detail hereinbelow.

In its most basic embodiment, the sole PGM in the catalytic converter for use in the present invention can be Pd. However, depending on the exhaust gas composition produced by the engine, it can be useful to include one or more non-Pd PGMs in the

catalytic converter, subject to the proviso that the atom amount of Pd present is in the majority over all other PGMs present. In preferred embodiments, the non-Pd PGM comprises platinum (Pt). Pt can be particularly useful for oxidising saturated HCs, and is, of course, used as a major component of conventional DOCs for treating SOF.

5

The at least one base metal promoter for the Pd catalytic component can be a basic metal element or a basic metal compound or any mixture of any two or more thereof. Illustrative examples of basic metals are alkaline earth metals, such as barium, magnesium, calcium or strontium, or a lanthanide metal, e.g. cerium or lanthanum, or
10 any mixture or mixed oxide of any two or more thereof.

In one embodiment, the basic metal compound is ceria, and the Pd is supported on particulate ceria, i.e. the particulate ceria serves as the Pd support and promoter.

15

Alternatively, the support for the or each PGM can be any conventional support known in the art such as alumina, silica-alumina, titania, zirconia, a zeolite or a mixture or mixed oxide of any two or more thereof, and can be doped, as conventional in the art, with a basic metal or basic metal compound. Non-limiting examples of the basic metal dopant are zirconium, lanthanum, alumina, yttrium, praseodymium, cerium, barium and
20 neodymium. The support can be, for example, lanthanum-stabilised alumina, or zirconium-doped ceria.

25

The catalytic converter can comprise a conventional substrate, such as a ceramic, e.g. cordierite, or metal, e.g. FecralloyTM, honeycomb. Where the sole PGM present is Pd, a single substrate can be coated with a washcoat including the supported Pd and the at least one base metal promoter. However, where the catalytic converter for use in the present invention includes at least one non-Pd PGM, we envisage that the catalytic converter can take one of several forms. In one embodiment, comprising a single substrate, the supported Pd and the at least one base metal promoter are coated on an
30 upstream part of the substrate and the at least one supported non-Pd PGM is coated on a downstream part thereof, although the non-Pd PGM can be upstream of the Pd if desired. In an alternative embodiment, also comprising a single substrate, the catalytic converter comprises a substrate comprising a first layer comprising the at least one supported

non-Pd PGM and a second layer overlying the first layer, which second layer comprising the supported Pd and the at least one base metal promoter. However, if desired, the non-Pd PGM can be in the overlayer and the Pd in the underlayer. In a third embodiment also comprising a single substrate, the substrate is coated with a single washcoat layer, which layer comprising the supported Pd, the at least one base metal promoter and at least one supported non-Pd PGM wherein each PGM is supported on a separate and distinct particulate support material. In an alternative embodiment, the catalytic converter comprises a first substrate comprising the supported Pd and the at least one base metal promoter and a second substrate comprising the at least one supported non-Pd PGM, which second substrate is disposed downstream of the first substrate. The order of the first and second substrates can be reversed, if desired.

In the new generation of diesel engine-installed vehicles, the engines may be controlled to operate in a mode generating low temperature exhaust gases, such as combustion of a substantially pre-mixed air-fuel charge, over the entire engine load-speed map. However, we envisage that at high loads, the engine control means switches the engine to more conventional diesel combustion as is used in direct injection diesel engines. During such periods of "direct injection" running, levels of NO_x and PM can require treatment in order for the vehicle as a whole to meet the relevant emission legislation.

According to this aspect, the invention provides a diesel engine according to the invention, having a first running condition wherein the engine is configured to run in a mode characterised by the amount of CO and HC produced in the defined temperature range, and a second condition wherein the engine is configured to run in a conventional direct injection diesel engine mode. Control of the first and second running conditions can be effected by the engine control means associated with the engine.

Methods of treating levels of NO_x and PM generated by conventional diesel engines are known and include: a particulate filter downstream of a catalytic converter for oxidising NO to O_2 whereby PM trapped on the filter is combusted in the NO_2 at temperatures of up to 400°C ; a NO_x -trap; a catalyst for catalysing the selective catalytic reduction (SCR) of NO_x with at least one NO_x specific reductant, such as a nitrogenous

compound, for example a nitrogen hydride, ammonia, an ammonia precursor, e.g. urea, and hydrazine; or a catalyst for catalysing the reduction of NO_x with at least one non-selective reductant, such as H_2 or at least one hydrocarbon. However, where the rate of such methods of treating NO_x and PM are low at the exhaust gas temperatures developed in the first mode, when the switch to second-mode running is effected by the engine control means, the downstream catalysts can be below their effective temperature for treating them.

A benefit of the invention, where downstream treatment of NO_x and/or PM is required, is that the CO exotherm developed over the catalytic converter can be used to raise the temperature of the downstream catalysts, thereby improving the overall conversion in the system. CO content of the exhaust gas in the second mode can be modulated according to exotherm requirement by suitable engine control using methods known in the art.

The catalysts for treating NO_x and/or PM can be any conventional composition known in the art. For example, the NO_x -trap can comprise a NO_x absorber, which can comprise an alkali metal compound or an alkaline earth metal compound. Additionally, the NO_x -trap can include at least one PGM, which can be selected from the group consisting of Pt, Pd and Rh, preferable and preferably a combination of Pt and Rh.

The SCR catalyst can be Pt-based, e.g. Pt on alumina; vanadium-based, e.g. $\text{V}_2\text{O}_5/\text{TiO}_2$; or a zeolite, e.g. ZSM-5, mordenite, gamma-zeolite or beta-zeolite. The zeolite can comprise at least one metal selected from the group consisting of Cu, Ce, Fe and Pt, which metal can be ion-exchanged or impregnated on the zeolite.

The particulate filter can be catalysed, e.g. by at least one of a NO oxidation catalyst, a NO_x absorber, an O_2 combustion catalyst or a catalyst for catalysing the SCR of NO_x .

Where the diesel engine according to the invention includes an exhaust gas recirculation valve and a circuit to recirculate a selected portion of the exhaust gas to the

engine air intake, desirably the exhaust gas is cooled prior to mixing with the engine intake air.

According to a further aspect, the invention provides a vehicle including a diesel engine according to the invention. The vehicle can be, for example, a light duty diesel vehicle as defined by the relevant legislation.

In order that the invention may be more fully understood reference is made to the following Examples by way of illustration only.

EXAMPLE 1

A 2wt% Pt-alumina-based catalyst (Catalyst A), a 2wt% Pd-alumina-based catalyst (Catalyst B), and a 2wt% Pd-ceria-containing catalyst (Catalyst C) were tested for HC and CO light-off in a simulated catalyst activity test (SCAT) gas rig. A sample of each catalyst was tested in the flowing gas mixtures set out in Table 1. The temperature of the gas mixtures used was increased during each test from 100°C to 500°C.

Table 1: Gas mixtures used for activity tests for Catalysts A, B, and C

	Gas Mixture 1	Gas Mixture 2	Gas Mixture 3	Gas Mixture 4
ppm HC (C1) as propene	600	900	3000	3000
ppm CO	200	600	25000	25000
ppm NO	200	200	200	200
% H ₂ O	4.5	4.5	4.5	4.5
% O ₂	12	12	12	3
% CO ₂	4.5	4.5	4.5	4.5
ppm SO ₂	20	20	20	20
N ₂	Balance	Balance	Balance	Balance
Flow Rate (litres/hour/g sample)	300	300	300	300
Ramp Rate (°C/min)	10	10	10	10

Gas mixtures 1 and 2 have HC and CO gas concentrations as typical of exhaust gases from a conventionally operated Diesel engine. Gas mixture 3 has higher HC and CO concentrations than gas mixtures 1 and 2 and gas mixture 4 has a lower oxygen concentration than used in gas mixtures 1 to 3. Tables 2 and 3 show the temperature at which 80% oxidation conversion of HC and CO was achieved over each catalyst.

Table 2: Temperature for 80% conversion (T80 HC/CO) of Catalysts A, B and C in gas mixtures 1-3

T80 HC / CO (°C)	Gas Mixture 1	Gas Mixture 2	Gas Mixture 3
Catalyst A	170 / <110	158 / 114	185 / 183
Catalyst B	264 / 265	253 / 247	205 / 203
Catalyst C	231 / 164	226 / 170	< 110 / <110

Catalyst A showed significantly higher activity than Catalyst B or C at lower temperatures for both HC and CO oxidation using the gas mixtures 1 and 2, but showed a loss in low temperature oxidation activity in the high HC and CO gas mixture 3. In contrast to the loss in activity in high HC, CO gas feeds for Catalyst A, Catalyst B showed a small improvement in low temperature oxidation activity from gas mixture 1 or 2 to gas mixture 3. However, despite the improved low temperature activity of Catalyst B for the higher HC and CO gas feed conditions, overall the activity of Catalyst B was poorer than that of Catalyst A. By contrast, Catalyst C showed lower activity under gas mixtures 1 and 2 relative to Catalyst A. However, in contrast to Catalyst A and Catalyst B, Catalyst C showed the highest activity for HC and CO oxidation at low temperatures under the high HC and CO gas concentration mixture 3.

Table 3 shows that the low temperature CO activity of Catalyst A was further decreased in gas mixture 4, consisting of 3% oxygen, compared to the activity measured in gas mixture 3, which included 12% oxygen. In contrast, the activity of Catalyst B was slightly improved in gas mixture 4 compared to gas mixture 3. The low temperature oxidation activity of Catalyst C remained very high in both gas mixtures 3 and 4.

Table 3: Temperature for 80% conversion (T80-CO) of Catalysts A, B and C in gas mixtures 3 and 4

T80 CO (°C)	Mixture 3	Mixture 4
Catalyst A	183	239
Catalyst B	203	197
Catalyst C	<110	<110

EXAMPLE 2

In another series of activity tests, Catalyst D (1wt% Pt-alumina-based), and Catalyst E (4wt% Pd-ceria-based), were tested for HC and CO light-off in a SCAT gas rig using the gas mixtures set out in Table 4, and the temperature of the gas passed over each sample was increased during each test from 100°C to 500°C.

Table 4: Gas mixtures used for activity tests of Catalysts D and E

	Gas Mixture 5	Gas Mixture 6	Gas Mixture 7	Gas Mixture 8	Gas Mixture 9
ppm HC (C1) as toluene	600	600	600	600	600
ppm CO	200	950	2000	10000	25000
ppm NO	200	200	200	200	200
% H ₂ O	4.5	4.5	4.5	4.5	4.5
% O ₂	12	12	12	12	12
% CO ₂	4.5	4.5	4.5	4.5	4.5
ppm SO ₂	20	20	20	20	20
N ₂	Balance	Balance	Balance	Balance	Balance
Flow Rate (litres/hour/g sample)	300	300	300	300	300
Ramp Rate (°C/min)	10	10	10	10	10

For each gas mixture from 5 to 9, the CO concentration was progressively increased and the remaining gases were kept constant with a nitrogen balance. Table 5 shows the effect of CO concentration on the HC and CO light-off of the catalysts.

Table 5: Temperature for 80% conversion (T80-HC/CO) of Catalysts D and E in gas mixtures 5 – 9.

T80 HC / CO (°C)	Gas Mixture 5	Gas Mixture 6	Gas Mixture 7	Gas Mixture 8	Gas Mixture 9
Catalyst D	188/112	192/158	194/185	212/210	231/217
Catalyst E	259/135	256/130	175/<110	<110/<110	<110/<110

Catalyst D showed a loss in low temperature activity as the CO concentration was progressively increased, whereas Catalyst E showed improved low temperature activity with higher CO gas feeds. We infer that the loss in activity for Catalyst D is because of self-poisoning of the active sites on the catalyst. It is well known that the strong adsorption of CO on the Pt active sites may block the adsorption of oxygen necessary for the oxidative reaction to form CO₂. Catalyst E does not show this self-poisoning behaviour, and the activity of this catalyst to oxidise CO in higher CO concentrations is significantly improved over Catalysts A and D

EXAMPLE 3

Further SCAT rigs tests on Catalyst D (1wt% Pt-alumina-based) and Catalyst E (4wt% Pd-ceria-based) were carried out using the gas mixtures with 25000ppm CO and two different HC concentrations (using either propene or toluene). A sample of each catalyst was placed in the gas mixtures shown in Table 6, and the temperature of the gas was increased from 100°C to 500°C. The concentration of HC (as C1) was increased from 600ppm to 3000ppm using either propene or toluene as the HC species. The activity of the catalysts tested is given in Table 7.

Table 6: Gas mixtures used for activity tests on Catalyst A and Catalyst C

	Gas Mixture 10	Gas Mixture 11	Gas Mixture 12	Gas Mixture 13
ppm HC (C1) as propene	600	3000	0	0
ppm HC (C1) as toluene	0	0	600	3000
ppm CO	25000	25000	25000	25000
ppm NO	200	200	200	200
% H ₂ O	4.5	4.5	4.5	4.5
% O ₂	12	12	12	12
% CO ₂	4.5	4.5	4.5	4.5
ppm SO ₂	20	20	20	20
N ₂	Balance	Balance	Balance	Balance
Flow Rate (litres/hour/g sample)	300	300	300	300
Ramp Rate (°C/min)	10	10	10	10

5 **Table 7: Temperature for 80% conversion (T80-CO/HC) of catalysts D and E in gas mixtures 10 - 13**

T80 HC / CO (°C)	Gas Mixture 10	Gas Mixture 11	Gas Mixture 12	Gas Mixture 13
Catalyst D	186/184	218/218	231/217	230/231
Catalyst E	<110/<110	<110/<110	<110/<110	<110/<110

10 For gas mixtures 10 and 12 (containing 25000ppm CO, 600ppm HC), Catalyst E showed the highest activity for HC and CO light-off. The light-off activity of Catalyst D deteriorated in gas mixtures 11 and 13 (containing 25000ppm CO, 3000ppm HC) relative to the activity found for gas mixtures 10 or 12. The activity of Catalyst E in all the gas
15 mixtures used remained higher than that of Catalyst D.

EXAMPLE 4

20 Further SCAT rig tests on Catalyst A, Catalyst B, and Catalyst C were carried out using gas mixtures with 10000ppm CO and four different HC concentrations (using propene). A sample of each catalyst was tested in the gas mixtures in Table 8, and the temperature of the gas was increased from 100°C to 500°C. The concentration of HC (as

C1) was increased from 600ppm to 4500ppm (propene). The activity of the catalysts is shown in Table 9.

Table 8: Gas mixtures used for activity tests of Catalysts A, B and Catalyst C

	Gas Mixture 14	Gas Mixture 15	Gas Mixture 16	Gas Mixture 17
ppm HC (C1) as propene	600	1800	3000	4500
ppm CO	10000	10000	10000	10000
ppm NO	200	200	200	200
% H ₂ O	4.5	4.5	4.5	4.5
% O ₂	12	12	12	12
% CO ₂	4.5	4.5	4.5	4.5
ppm SO ₂	20	20	20	20
N ₂	Balance	Balance	Balance	Balance
Flow Rate (litres/hour/g sample)	300	300	300	300
Ramp Rate (°C/min)	10	10	10	10

Table 9: Temperature for 80% conversion (T₈₀-CO/HC) of Catalysts A, B and C in gas mixtures 14 – 17.

C ₃ H ₆ ppm	Catalyst A		Catalyst B		Catalyst C	
	CO T ₈₀	C ₃ H ₆ T ₅₀	CO T ₈₀	C ₃ H ₆ T ₅₀	CO T ₈₀	C ₃ H ₆ T ₅₀
600	159	156	169	176	121	<110
1800	159	165	179	177	130	134
3000	161	162	179	177	136	135
4500	161	170	180	179	133	142

Catalyst C exhibits the highest activity for HC and CO oxidation in the gas feed that contained 600ppm HC. Catalyst B had the poorest activity. Increased levels of HC caused a slight drop in catalyst activity, but even at the highest HC levels Catalyst C had much lower temperature activity for oxidation light-off compared to Catalysts A and B.

CLAIMS:

1. A process for treating an exhaust gas from a diesel engine, which exhaust gas comprises >2000ppm carbon monoxide (CO) and >500ppm C₁ unburnt hydrocarbon (HC) below 250°C during normal operating conditions measured at the exhaust manifold, which process comprising contacting the exhaust gas with a catalyst comprising at least one supported Platinum Group Metal (PGM) and at least one base metal promoter, wherein the at least one PGM is palladium (Pd) and wherein the atom amount of Pd present is in the majority over all other PGMs present.
2. A process according to claim 1, wherein the PGM comprises also platinum (Pt).
3. A process according to claim 1 or 2, wherein the exotherm produced over the catalyst is used to increase the rate of a downstream process step.
4. A process according to claim 3, wherein the downstream process step comprises NO_x adsorption, NO_x desorption, particulate matter combustion in NO₂ or O₂, NO_x reduction using a NO_x specific reductant or NO_x reduction using a non-selective reductant, such as hydrogen (H₂) or at least one hydrocarbon.
5. A process according to any preceding claim, wherein the diesel engine combusts a substantially pre-mixed air-fuel charge.
6. A process according to any preceding claim, wherein the diesel engine is a homogeneous charge compression ignition (HCCI).
7. A diesel engine producing an exhaust gas comprising >2000ppm carbon monoxide (CO) and >500ppm C₁ unburnt hydrocarbon (HC) below 250°C during normal operating conditions measured at the exhaust manifold, which engine comprising an exhaust system comprising a catalytic converter, which catalytic converter comprising at least one supported Platinum Group Metal (PGM) and at least one base metal promoter, wherein the at least one PGM is palladium (Pd) and wherein the atom amount of Pd present is in the majority over all other PGMs present.

8. A diesel engine according to claim 7, wherein at least one supported PGM comprises also platinum.

5 9. A diesel engine according to claim 7 or 8, wherein the base metal promoter is a basic metal element or a basic metal compound or any mixture of any two or more thereof.

10 10. A diesel engine according to claim 9, wherein the basic metal is an alkaline earth metal or a lanthanide metal or any mixture or mixed oxide of any two or more thereof.

11. A diesel engine according to claim 9, wherein the alkaline earth metal is barium, magnesium, calcium, strontium or any mixture or mixed oxide of any two or more thereof.

15 12. A diesel engine according to claim 9, wherein the lanthanide metal is cerium or lanthanum.

20 13. A diesel engine according to any of claims 7 to 12, wherein the or each PGM support is alumina, silica-alumina, ceria, titania, zirconia, a zeolite or a mixture or mixed oxide of any two or more thereof.

14. A diesel engine according to claim 13, wherein the support is doped with a basic metal or basic metal compound.

25 15. A diesel engine according to claim 14, wherein the basic metal or basic metal compound is one or more of zirconium, cerium, lanthanum, alumina, yttrium, praseodymium, barium and neodymium.

30 16. A diesel engine according to claim 13, 14 or 15, wherein the support comprises lanthanum stabilised alumina.

17. A diesel engine according to claim 13, 14 or 15, wherein the support comprises zirconium-doped ceria.
18. A diesel engine according to any of claims 7 to 17, wherein the catalytic converter comprises at least one substrate.
19. A diesel engine according to claim 18, wherein the catalytic converter comprises a first substrate comprising the supported Pd and the at least one base metal promoter and a second substrate comprising the at least one supported non-Pd PGM, which second substrate is disposed downstream of the first substrate.
20. A diesel engine according to any of claims 8 to 18, wherein the catalytic converter comprises a substrate comprising the supported Pd and the at least one base metal promoter on an upstream part of the substrate and the at least one supported non-Pd PGM on a downstream part thereof.
21. A diesel engine according to any of claims 8 to 18, wherein the catalytic converter comprises a substrate comprising a first layer comprising the at least one supported non-Pd PGM and a second layer overlying the first layer, which second layer comprising the supported Pd and the at least one base metal promoter.
22. A diesel engine according to any of claims 8 to 18, wherein the catalytic converter comprises a substrate coated with a single washcoat layer, which layer comprising the supported Pd, the at least one base metal promoter and the at least one supported non-Pd PGM, wherein each PGM is supported on a separate and distinct particulate support material.
23. A diesel engine according to any of claims 7 to 22, having a first running condition wherein the engine is configured to run in a mode which produces the defined levels of CO and HC in the defined temperature range, and a second condition wherein the engine is configured to run in a conventional direct injection diesel engine mode.

24. A diesel engine according to claim 23, wherein the engine switches to the second condition during high engine load.
25. A diesel engine according to claim 23 or 24, wherein the first and second running
5 conditions are controlled by an engine control means.
26. A diesel engine according to claim 23, 24 or 25, wherein the exhaust system comprises a NO_x trap downstream of the catalytic converter.
- 10 27. A diesel engine according to claim 23, 24 or 25, wherein the exhaust system comprises a catalyst for catalysing the selective catalytic reduction (SCR) of NO_x with at least one NO_x specific reductant.
- 15 28. A diesel engine according to claim 23, 24 or 25, wherein the exhaust system comprises a catalyst for catalysing the reduction of NO_x with at least one non-selective reductant, such as H₂ or at least one hydrocarbon.
- 20 29. A diesel engine according to claim 23, 24 or 25, wherein the exhaust system comprises an optionally catalysed particulate filter downstream of the catalytic converter.
30. A diesel engine according to any of claims 7 to 29, including an exhaust gas recirculation valve and circuit to recirculate a selected portion of the exhaust gas to the engine air intake.
- 25 31. A diesel engine according to claim 30, wherein the recirculated exhaust gas is cooled prior to mixing with the engine intake air.
32. A diesel engine according to any of claims 7 to 31 which combusts a substantially pre-mixed air-fuel charge.
- 30 33. A diesel engine according to any of claims 7 to 32, wherein it is a homogeneous charge compression ignition (HCCI) diesel engine or a Dilution Controlled Combustion System (DCCS) diesel engine.

34. A vehicle including a diesel engine according to any of claims 7 to 33.

35. A light duty diesel vehicle according to claim 34.

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36. A diesel engine substantially as described herein.

37. A process of treating an exhaust gas from a diesel engine substantially is described herein with reference to the accompanying Example.

PROCESS FOR TREATING DIESEL EXHAUST GAS

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Abstract

10 A process for treating an exhaust gas from a diesel engine comprising >2000 ppm carbon monoxide and >500 ppm C₁ unburnt hydrocarbon below 250°C during normal operating conditions measured at the exhaust manifold comprising contacting the exhaust gas with a catalyst comprising at least one supported Platinum Group Metal (PGM) and at least one base metal promoter, wherein the at least one PGM is palladium (Pd) and wherein the atom amount of Pd present is in the majority over all other PGMs present.

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PCT Application
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